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Eco-systems for young digital innovators

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Abstract:

This contribution takes a closer look at innovation in ICT sectors and the failing ability of young innovative firms in Europe to grow into leading world innovators in these sectors. The analysis suggests that Europe might be missing strong digital regional clusters with a symbiotic relationship between young ICT innovators and incumbent ICT leading companies.

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1. Introduction

By now, it is well known that ICT sectors are major contributors to innovation and growth (eg Collechia & Schreyer (2002), Timmer & Van Ark (2005)). It is equally well known that Europe has an ICT innovation and growth problem relative to the US (Moncada et al. (2009), IPTS PREDICT (2010), EC (2011), Strauss & Samkharadze (2011)). Not only has Europe (compared to the US) a lower specialization on average in ICT sectors, it also misses to focus on those new ICT subsectors and firms where most opportunities for ICT based growth are located. Europe is missing young leading innovators in these areas (Cincera & Veugelers (2013).

This contribution takes a closer look at, and provides some recent evidence on, Europe's innovation potential in ICT sectors and its failing ability to develop strongholds in the new, most dynamic ICT subsectors and the potential of its young innovative firms to grow into leading world positions in these sectors (Sections 2-4). It examines in more detail Europe's regional clustering of young and incumbent ICT firms (Section 5). The analysis shows that Europe might be missing strong digital clusters with a symbiotic relationship between young and incumbent leading ICT innovators, suggesting a systems' failure behind Europe's failing ICT innovation potential. The contribution closes with a few tentative policy implications (Section 6).

2. Europe's ICT innovation problem diagnosed

We start the analysis by providing evidence to diagnose the problem of Europe's business ICT sector to generate growth. It focuses on the capacity to innovate by Europe's ICT firms as a fundamental component of growth. This capacity to innovate is proxied by the firms' incentives to invest in R&D. We use the IPTS Scoreboard data of 2500 largest R&D spenders globally to characterize the differences in R&D investment behavior of the corporate ICT sector across the various regions in the world. Although the Scoreboard analysis focuses on the input side of innovation, lower R&D investments are interpreted as symptomatic of a more broader problem of lower incentive to innovate and lower ability to capture value from innovation. Patent data would be an alternative, complementary way to characterize the innovative behavior of firms in the ICT sector. Dernis et al (2015) traced the patent activities of all Scoreboard firms and confirms that almost all of them indeed hold at least one patent application. Particularly ICT Scoreboard firms have a high propensity to protect their inventions through patents and trademarks (Dernis et al (2015)). But as the propensity to patent inventions is very specific for different (sub)technologies and regions, making comparisons across (sub)technologies and regions with patent data is more tricky.

Table 1a and 1b characterize the R&D landscape in ICT worldwide using the Scoreboard data. The ICT sector includes both ICT manufacturing and services. Table 1a shows how pivotal the ICT sector is in the overall R&D landscape: more than one third of all Scoreboard firms are ICT, representing more than one third of all Scoreboard R&D expenditures. Firms in the ICT sector are almost twice as R&D intensive compared to all sectors and have a higher R&D growth than average. Table 1b shows how "young" the

ICT R&D landscape is: three quarters of all ICT scoreboard firms are “young”, ie born after 1970, one quarter is born after 2000. These “young” leading innovators, although still smaller in sales and R&D-size than their older counterparts, have a higher R&D intensity and a higher growth rate in R&D.

Table 1a: ICT in global leading R&D (2013)

R&D-to-Sales ratio (RDI); All sectors	3.2%	
R&D-to-Sales ratio (RDI); ICT sectors	6.1%	
R&D growth (2010-2013); All sectors		6.4%
R&D growth (2010-2013); ICT sectors		7.75%
Share ICT in total Scoreboard sales		18.3%
Share ICT in total Scoreboard R&D		34.6%
Share ICT in total number of Scoreboard firms		35%

Source: Own calculations on the basis of JRC-IPTS-R&D Scoreboard of the 2500 largest R&D spenders globally (2015); The year of R&D expenditures is 2013. These 2500 firms represent in 2013 about 538.298 mill Euro in R&D expenditures, 167.230.001 mill Euro in sales. ICT sectors include electronics, technology hardware, mobile & fixed line telecommunications services, software & computer services . R&D growth is calculated as the CAGR in R&D expenditures over the period (2010-2013)

Table 1b: Young firms in ICT global leading R&D (2013)

	All	**OLD**	**YOUNG**	**Youngest**
Number of ICT R&D Scoreboard firms	2500	873	656	222
Share in total ICT Scoreboard firms	100%	25%	75%	25%
Share in total ICT Scoreboard R&D expenditures	100%	43%	57%	9%
Share in total ICT Scoreboard Sales	100%	54%	46%	8%
R&D-to-Sales ratio (RDI);	6.1%	4.9%	7.5%	6.9%
Growth in Scoreboard R&D (2010-2013)	7.75%	2.8%	12.1%	15.5%
Growth in Scoreboard Sales (2010-2013)	4.4%	2.15%	7.4%	8.3%

Source: Own calculations on the basis of JRC-IPTS-R&D Scoreboard of the 2500 largest R&D spenders globally in year 2013. Young is born after 1970 of which Youngest are born after 2000.

Tables 2a-c characterize the position of the different regions in the global R&D landscape. Table 2a shows the strength of the US in the overall business R&D landscape, representing 36% of all global Scoreboard R&D. US scoreboard firms have a much higher R&D-to-sales ratio (RDI) compared to Europe and Asia. The same holds true for the ICT sector, but the weak position of Europe is even more pronounced. Although the ICT sector has also in the European economy an above average R&D intensity, the European ICT sector carries much less weight in its total R&D and Scoreboard sales compared to the US and Asia. This confirms the lower specialisation of Europe in ICT compared to the US and Asia. In addition, leading European ICT innovators have a much smaller R&D-to-Sales ratio (RDI) than their US counterparts and a smaller growth in R&D investments.

Table 2a: Regions in global leading R&D (2013)

	ALL	EUR	US	Asia
Number of global R&D Scoreboard firms	2500	709	804	807
Region's share in global R&D Scoreboard Number of Firms	100%	28%	32%	32%
Region's share in global R&D Scoreboard R&D expenditures	100%	34%	36%	26%
R&D-to-Sales ratio (RDI);	3.2%	2.9%	5.0%	2.5%

Source: Own calculations on the basis of JRC-IPTS-R&D Scoreboard of the 2500 largest R&D spenders globally in year 2013. EUR includes the EU-28 together with Switzerland and Norway. RoW is not reported (It includes beyond Canada, Central and Latin America, Russia, Africa and Australia also a substantial number of firms from Cayman Islands, Bermuda etc…)

Table 2b: Regions in global leading R&D in ICT (2013)

	ALL	EUR	US	Asia
Number of ICT global R&D Scoreboard firms	873	164	355	270
Region's share in ICT global R&D Scoreboard Number of Firms	100%	19%	41%	31%
Region's share in ICT global R&D Scoreboard R&D expenditures	100%	19%	49%	27%
R&D-to-Sales ratio (RDI); ICT sectors	6.2%	5.5%	8.6%	4.2%
R&D growth (2010-2013)	7.75%	2.2%	10.25%	6.7%
Sales growth (2010-2013)	4.4%	-0.1%	6.5%	5.0%

Source: Own calculations on the basis of JRC-IPTS-R&D Scoreboard of the 2500 largest R&D spenders globally in year 2013.

Table 2c: Regions and young firms in global leading R&D in ICT (2013)

	ALL	EUR	US	Asia
Number of Young ICT Scoreboard Firms [2]	656	100	293	183
Number of Youngest ICT Scoreboard Firms	222	30	115	32
Share of Young in Region's total ICT Scoreboard Number of Firms	75%	61%	82.5%	68%
Share of Youngest in Region's total ICT Scoreboard Number of Firms	25%	18%	32%	12%
Share of Young in Region's total ICT Scoreboard R&D expenditures	57%	35.5%	72%	39%
Share of Youngest in Region's total ICT Scoreboard R&D expenditures	9%	10%	8%	6%
R&D-to-Sales ratio (RDI); Old ICT firms	4.9%	5.2%	5.4%	4.4%
R&D-to-Sales ratio (RDI); Young ICT firms	7.5%	6.2%	11.1%	3.8%
R&D-to-Sales ratio (RDI); Youngest ICT firms	6.9%	8.0%	13.4%	2.5%
R&D growth (2010-2013); Young ICT firms	12.1%	9.7%	12.8%	10.6%
Sales growth (2010-2013); Young ICT firms	7.4%	0.95%	12.1%	5.4%

Source: Own calculations on the basis of JRC-IPTS-R&D Scoreboard of the 2500 largest R&D spenders globally in year 2013. *Young* is born after 1970 of which *Youngest* are born after 2000.

Table 2c shows that this R&D intensity gap for Europe relative to the US holds for old, but especially for young ICT innovators. It is particularly the group of young US ICT firms which have a R&D intensity edge over their EU counterparts and also over their older US counterparts. These young US ICT world leading innovators are much more prominently present in the US ICT landscape than in Europe. These include for the US, "unicorns" like Apple, Microsoft, Google, Yahoo, Amazon, Facebook, Twitter, Oracle. For Europe, these include SAP, Ubisoft. While the US counts 293 firms in the Scoreboard born after 1970 (115 after 2000), Europe has only 100 (30 born after 2000). And this matters, as these firms are more R&D intensive than older ICT firms and have a higher R&D growth rate. Europe's struggling R&D position in ICT seems therefore related to its failure to nurture enough new ICT firms that have been able to grow and become world leading innovators. Asia has an even more pronounced age problem with its ICT leading innovators.

The numbers from Table 1 allow for an interesting "what-if" scenario for closing Europe's ICT R&D performance gap with the US. We can calculate what Europe's R&D performance would be in ICT, if it would have the same calibre of young ICT innovators as the US, with an equal weight in its ICT landscape and an equal R&D intensity as in the US. Even without requiring higher R&D intensities of its older incumbent ICT innovators, Europe would in this case have a 73% higher ICT RDI and thus have closed its business RDI ICT gap with the US. And if Europe would succeed in getting its current stock of young ICT innovators to have the same incentive to invest in R&D as their US counterparts, it would have a 51% higher R&D intensity in ICT. Less effective would be to increase the share of young ICT innovators to the US levels, but of the same calibre as the current stock, i.e. with European R&D intensities. In this case, Europe's overall ICT R&D intensity would only be 4% higher. A more crucial parameter to address Europe's lagging ICT R&D performance is therefore the lower inclination of European young ICT innovators to invest in R&D rather than their smaller number.

3. The post-internet digital innovation eco-system

What explains why Europe has few young ICT leading global innovators and why its young ICT firms have a lower inclination to invest in R&D? For this we have to look deeper within the ICT sector and the position that European firms hold in the different subsectors of the post-internet digital eco-system.

The term **innovation eco-system** is used to describe the large and diverse array of participants and resources that contribute to and are necessary for innovation. This includes entrepreneurs, investors, researchers, university faculty, venture capitalists, (lead) users and customers among others (Adner (2006), Dosso et al (2015)). In the remainder of this contribution we will look at the composition of the innovation eco-system in ICT and how it has shifted over time, with the advent of Internet. Our focus will be on the supply side of the digital eco-system. We will look at shifts in the type of technologies and services digital companies are supplying and their company age structure. This will allow us to understand better the dynamics in the supply side of the digital innovation eco-system.

3.1. The different layers in the post-internet digital eco-system

The supply side of the ICT eco-system is typically categorized as involving three types of firms (eg Fransman (2010)):

- Layer I: Network element providers (e.g. Cisco, Samsung, Alcatel, Ericson, Nokia, Apple…),
- Layer II: Network operators (fixed and mobile) (e.g. AT&T, BT, DT, Vodafone..),
- Layer III: Software & ICT service providers; Platform, application providers (e.g. Google, Facebook, SAP…).

With the advent of the internet economy, most change has occurred in layer III. Software, connectivity, navigation and middleware became the new drivers of the industry, disrupting the traditional telecommunications industry, concentrated more in Layer I and II. In the new digital eco-system, companies can vertically specialize in Layer III, offering applications and services without owning any network facilities. The two historical "hardware" layers (Equipment & Network operators) have become "commoditized" by the upper "software" layer. It has forced the incumbent firms from Layers I and II to search for new business models to capture value in the new digital value chain. As data traffic continues to increase at explosive rates, driven by the massive uptake of smartphones and tablets, the mobile Internet, and digitization technologies such as cloud computing, telecom operators in Layer II need to invest heavily in their networks to upgrade. Telecom operators are looking for ways to better monetize the flow of traffic over their networks and capture considerably more of the revenue now going to Internet players.

3.2. The competition landscape in the post-internet digital eco-system

A good understanding of the competition between the firms in the post-internet digital eco-system is important to better understand their prospects for growing into world leading innovators and capturing the value from their innovations.

3.2.1. Platform competition

Most of the competition in the new ICT eco-system is competition between platforms 'for the market' rather than 'in the market'. Compatibility and (inter and intra) platform competition are important determinants of the size of the markets and the incentives to innovate. They are also important in determining which part of the eco-system is capturing most of the value: customers, platform providers, developers, equipment providers, or telecom providers.

A platform is basically a framework provided by platform owners to launch software or services. It is a system with well-defined access points and rules on which other parties can build applications or services (Zhu & Iansiti (2007)). Examples of platforms are Microsoft Windows, Linux, and Google's Chrome operating systems. In the mobile sector, there is Google's Android and Apple's IoS. Perhaps the best example of the power of a technology platform is Apple's iPhone. The iPhone platform took the smartphone leadership away from Nokia's Symbian platform. This displaced the gravity center of the smartphone market from the EU to the USA. Google's "fast-follower" strategy further expanded the impact of smartphones. Its Android platform opened the door for other smartphone hardware suppliers to compete with the iPhone eco-system.

Platforms are characterized by their two-sided nature. Platform providers must get both consumers and developers of complementary applications on board in order to succeed. Different business models for platforms will typically co-exist in the market. Rochet and Tirole (2003) discuss the various pricing schemes with platform competition and two-sidedness, and stress the multitude of different business models. Whether platform providers versus application providers can capture value will depend on their bargaining position inside the platform (within platforms competition) and the strength of the competition with other platforms (between platforms competition).

In the competition between platforms, platform providers decide whether they develop their platform in compatibility with others or not (open or closed model). Casadesus & Ruiz (2009) study the concept of inter-platform competition while taking into account the aforementioned two-sided features of the market. When compatibility is in place (open model), there is more competition for developers, which are in a better bargaining position. As a consequence, access prices are lower in compatible than in incompatible platforms (ceteris paribus), and therefore market entry for developers is presumably easier. With more entry of developers, the total size of the market and the total value creation will be higher for compatible platforms. This explains the preference of policy makers for compatibility. Nevertheless, despite this market size advantage, platform providers may shun open platforms and choose for incompatibility of their network as this has the prospect of leaving higher market dominance (albeit in a smaller overall market).   Free market forces could therefore lead to incompatible platforms.

3.2.2. Scale, entry and incumbency (dis)advantages

Having large scale is an advantage in platform-based sectors. The benefits mostly emerge from network effects operating on the two sides of the market: a large user base and a large base of applications and equipment. These two-sided network effects create a major barrier to entry for new entrants, and a strong advantage for established incumbents. The latter have their existing networks with their own customers and equipment and application providers, making it more difficult for potential entrants to build their own networks.   These entry barriers are larger when there are high switching costs between incompatible networks and applications (see eg Chapters 20 & 21 in Belleflamme & Peitz (2015)).

Nevertheless, as technology changes rapidly, incumbent advantages may also be quickly depreciated. New entrants offering radical innovations can quickly surpass existing entry barriers. This feature of new digital sectors constantly challenges incumbent positions. For rapidly changing technologies, it is sometimes difficult to delineate what is the industry, and hence what are its entry barriers and which are the incumbents. Entry barriers of new ICT segments are usually low, but once niches or new markets have been created and occupied, entry barriers can quickly raise due to the existence of network effects.

3.2.3. Competition and cooperation between new and incumbent firms

The relationship between new firms and incumbents is often seen as one of competition, where the start-up innovation spurs the Schumpeterian "gale of creative destruction" and destroys the existing sources of market power. However, industry studies suggest a more nuanced relationship (Gans, Hsu & Stern 2002). Besides creative destruction, where start-up innovations earn their rents through product market entry and "competition" with more established firms, there is also ample evidence of "cooperation" between start-up innovators and more established firms. Most successful innovations typically come from new start-up companies, particularly the more radical type of innovations. But as these start-ups face problems accessing finance and markets for their growth ambitions and as firms need complex combinations of different tools to provide 'solutions' and given the importance of complementary assets such as a well established reputation or brand recognition, and the supra discussed network effects, the most prevalent growth path for successful digital start-ups involves large incumbent firms, acquiring their technology, corporate venture funding them, forming strategic alliances with them or outright acquiring them. For a nice description of the role played by acquisitions of incumbents of start-ups in the EDA (Electronic Design Automation) industry, see Henkel, Ronde & Wagner (2010)[1]. When buying up these new entrants, large incumbent firms possibly develop further the acquired innovations, but they may also shelve the inventions if too disruptive for their incumbent business. How easy entry will be, whether the market structure will be one of competition versus cooperation between entrants and incumbents and who can capture most value within the bargaining between entrants and incumbents is determined by the interplay between the strength of the intellectual property protection and the effectiveness of complementary asset ownership (Gans, Hsu & Stern, 2002; Teece (1986)).

4. Europe's position in the post-internet digital innovation eco-system

With the changes in the ICT innovation eco-system post-internet, opening up new opportunities for new firms with new technologies, and the shifts in the competition arena between new and incumbent firms, Europe's lagging innovation potential in ICT could be accounted for by its failure to grab the Internet disruption. In this section, we examine Europe's position in the post-internet ICT innovation eco-system in more detail, looking at the different layers and their age composition.

4.1. Market trends for ICT goods and services by layers and regions

When looking at the supply side of the ICT sector, Perrin & Pouillot (2015) illustrate the different trends by Layer and by Region, based on the world largest publicly listed ICT companies. [2]

Table 3a: The ICT supply side by layer

Layer	Share in total Revenue (2013)	Growth in Revenue CAGR 2008-2013	Share in Investment (CAPEX)

[1] The EDA industry is a subsegment of the semiconductor industry, providing tools that support the automated design of integrated circuits.

[2] The 500 largest listed ICT companies represent about 90% of the revenues of all listed ICT companies. Although many firms cross different layers, firms and their revenues and expenditures are allocated to their main subsectors on the basis of their main line of activities. Likewise, although firms' activities cross different regions, revenues and expenditures are allocated to the region of the firms' main region of activities.

I: Equipment	37%	4%	20%
II: Network Operators	30%	4%	62%
III: IT services & Software	17%	1%	7%
III: Intermediation/Internet	6%	25%	4%
III: Content Providers	11%	3%	6%
TOTAL	100%	4%	100%

Source: Based on Perrin & Pouillot (2015), in turn based on Thomson Reuters 447 largest listed ICT companies (Excl semiconductors)

Table 3a shows that the Intermediation/Internet providers part of Layer III, is still the smallest in terms of world revenues, but it is the most dynamic. It records the highest growth rates in revenues. Layer II is the layer which takes the highest share of capital investments.

Table 3b shows how the different regions are positioned in the ICT layer structure. While the manufacturing component in Layer I has been mostly outsourced to Asia, the US has a strong position in Layer III. This holds particularly in the pivotal and most dynamic intermediation/internet sublayer, where the US hold almost exclusively the world market. Europe is retrenching in Layer I and fails to have a marked foothold in Layer III, particularly in the Intermediation/Internet sublayer. Its strongest position is in Layer II (operators). Large EU companies have a strong position in revenues in Layer II, which is the layer with limited growth potential but heavy capital expenditures, as documented in Table 3a.

Table 3b: The ICT supply side: by region and layer

	Revenue Growth CAGR 2009-2013			Share in Total Regional ICT Revenues 2013		
Layer	US	EU	Asia	US	EU	Asia
I: Equipment	10%	1%	4%	29	10	57
II: Network Operators	5%	-1%	9%	21	58	28
III: IT services and Software	7%	-3%	10%	26	15	8
III: Intermediation/Internet	14%	26%	48%	10	1	3
III: Content Providers	7%	3%	4%	15	16	4

Source: Based on Perrin & Pouillot (2015), in turn based on Thomson Reuters 384 largest listed ICT companies.

4.2. Innovation profile of the ICT eco-system: by layer and region

For our analysis, we are particularly interested in the innovation profiles of the different layers. The following tables detail the number of world leading innovators (i.e. scoreboard firms) in ICT and its different layers.

Table 4a: The innovation structure of the layered ICT eco-system (2013)

	ALL	Layer I	Layer II	Layer III
		Electronic Equipment,	Telecom Operators (Fixed and Mobile)	Internet; Software; IT services

		Technology Hardware & Equipment		
Share in ICT Scoreboard Firms	**100%**	66%	3%	31%
Share in ICT Scoreboard R&D	**100%**	27%	5%	68%
Share in ICT Scoreboard Sales	**100%**	67%	17%	16%
R&D Intensity (RDI)	**6.1%**	6.25%	1.6%	10.4%
Scoreboard R&D growth (2010-2013	**7.75%**	6.9%	0.65%	11.4%
Scoreboard Sales Growth (2010-2013	**4.4%**	5.1%	-0.6%	7.7%

Source: R&D data are based on the EC-IPTS Scoreboard firms from ICT; JRC-IPTS-Scoreboard (2015)

The most R&D intensive layer is Layer III (Internet; Software; Services). It is also the layer with the highest growth in R&D (as well as sales). Layer II is the least R&D intensive layer (Telecom Operators). It also has the lowest growth in R&D and Scoreboard Sales.

Table 4b: The age structure of the layered ICT innovation eco-system (2013)

	ALL	**Layer I**	**Layer II**	**Layer III**
		Electronic Equipment, Technology Hardware & Equipment	Telecom Operators (Fixed and Mobile)	Internet; Software; IT services
% Young in ICT Scoreboard Firms	**75%**	67%	52%	93%
% Youngest firms	**25%**	19%	*	40%
% Young in ICT Scoreboard R&D	**57%**	48%	23%	85%
% Youngest	**9%**	7%	*	15%
R&D Growth (2010-2013) Young	**12.1%**	11.4%	2.2%	13.7%
R&D Growth (2010-2013) Youngest	**15.5%**	7.3%	*	29.8%
R&D Growth (2010-2013) Old	**2.8%**	3.3%	-0.4%	1.1%
RDI Young	**8.3%**	6.5%	1.5%	12.9%
RDI Youngest	**6.7%**	4.9%	*	12.9%
RDI Old	**4.9%**	6.0%	1.7%	5.0%

Source: R&D data are based on the EC-IPTS Scoreboard firms from ICT; JRC-IPTS-Scoreboard (2015)

Note: *= Not reported as only 2 Scoreboard firms in Layer II are born after 2000.

The dynamics within Layer III can be related to the age structure of its leading innovators. Layer III is the layer with the highest share of "young" and "youngest" world leading innovators, while Layer II is the "oldest". It is only in Layer III that the young/youngest leading innovators have a higher R&D intensity compared to the incumbents. The few older companies in this layer (like IBM, Unisys, Nixdorf, Tata, Wipro) are situated in the IT services component which is the least R&D and dynamic subcomponent of Layer III.

Tables 5(a-b) look at the different positions of the regions in the ICT Layer structure. They allow to look at whether Europe's overall weak position in ICT is due to a missing presence in the most innovative, dynamic layers in the ICT eco-system, most notably Layer III.

Table 5a: R&D in ICT by Layer and Region (2013)

LAYER I				LAYER II				LAYER III			
ALL	EUR	US	ASIA	**ALL**	EUR	US	ASIA	**ALL**	EUR	US	ASIA
Share of Layer in Region's Number of ICT Scoreboard Firms											
66	59	55	86	**3**	9	2	3	**31**	32	43	11
Share of Layer in Region's ICT Scoreboard R&D											
68	69	57	88	**5**	13	2	5	**27**	18	41	7
Share of Layer in Region's ICT Scoreboard Sales											
69	45	62	82	**17**	46	9	10	**16**	9	29	7
R&D Intensity RDI											
6.25	8.4	8.0	4.4	**1.6**	1.5	1.4	2.1	**10.4**	10.7	12.3	3.8
R&D Growth (2010-2013)											
6.9	0.75	9.4	5.2	**0.65**	-0.8	7.2	-1.3	**11.4**	11.5	11.5	0

Note: Layer I: Hardware & Equipment; Layer II: Network Operators; Layer III: IT Services & Software, Platform, content and application providers
Source: Own calculations on the basis of IPTS Scoreboard (2015).

Table 5a confirms that Asia is specializing in Layer I, Europe in Layer II and the US in Layer III. This holds when looking at the number of ICT Scoreboard firms, their R&D expenditures and their Sales. Europe is overrepresented in the least R&D intensive layer II and underrepresented in the most R&D intensive layer III. Looking within each layer, EU firms are not underperforming relative to their US counterparts with respect to their R&D intensity. Only in Layer III is there is small gap with the US. The European problem is therefore not a within-layer underperformance, but a problem of not being sufficiently present in the most innovative and growing layer III: a "between-layer " problem rather than a "within-layer" problem. If Europe would have the same distribution of its ICT firms across the different layers as the US, but with its own European layer RDI, it would have almost the same overall ICT R&D intensity as the US. It would have closed its ICT RDI gap with the US by 93%. Asia however does not only have a "between-layer" problem, ie not being present enough in Layer III, it also has a "within-layer" problem in Layer III. But also in Layer I, where most of its R&D scoreboard firms are concentrated, it has a much lower R&D intensity than its European and US counterparts.

Table 5b shows the age structure of the ICT scoreboard firms by region. Layer III is a "young" layer in all regions. Young ICT scoreboard firms in this layer have a higher RDI than their older counterparts also in Europe, but especially in the US, not in Asia. The few old firms in Layer III in Europe (eg Nixdorf) are even somewhat more RDI than their older US counterparts (eg IBM, Unisys)[3]. In Layer I, the US has more young ICT scoreboard firms which are more R&D intensive and with a higher growth in R&D (esp in the semiconductors subsector), while Europe has more old ICT scoreboard firms which are more R&D intensive but are retrenching in R&D expenditures.

Table 5b: Age structure of R&D in ICT by Layer and Region (2013)

LAYER I				LAYER II				LAYER III			
ALL	EUR	US	ASIA	**ALL**	EUR	US	ASIA	**ALL**	EUR	US	ASIA
Share of Young in ICT Scoreboard Firms											
67	35	72	48	**52**	27	85	71	**93**	87	95	85
Share of Young in ICT Scoreboard R&D											
48	15	63	19	**23**	*	*	*	**85**	93	88	24
R&D Intensity RDI of Young ICT Scoreboard Firms											
6.5	7.8	9.1	5.2	**1.5**	*	*	*	**12.9**	11.1	14.5	3.9
R&D Intensity RDI of Old ICT Scoreboard Firms											
6.0	8.25	6.7	4.9	**1.7**	*	*	*	**5.0**	6.8	5.9	*
R&D Growth of Young ICT Scoreboard Firms											
11.4	8.9	12.7	10.6	**2.2**	*	*	*	**13.7**	12.0	12.8	17.2
R&D Growth of Old ICT Scoreboard Firms											
3.3	-1.5	4.7	6.3	**-0.4**	*	*	*	**1.1**	4.9	3.8	*

Note: Layer I: Hardware & Equipment; Layer II: Network Operators; Layer III: IT Services & Software, Platform, content and application providers; * Not reported because of too few observations;
Source: Own calculations on the basis of IPTS Scoreboard (2015).

With the post-internet ICT eco-system shifting power inside the system to platform, content and application providers, these numbers clearly show how poorly positioned Europe is in the post-Internet ICT innovation ecosystem, holding less world leading innovators in Layer III, which are typically young, highly R&D intensive world leading innovators with expanding R&D budgets. Europe's struggling R&D position in the ICT eco-system is therefore clearly related to its age-layer composition and its failure to sufficiently redirect with young innovators towards Layer III.

5. A system's failure in Europe's ICT? some evidence on regional ICT eco-systems in Europe

Why is it that, unlike the US, Europe has failed to nurture young innovators in the new ICT growth sectors, particularly in the layer of software, internet, intermediation, which offer the greatest opportunities for

[3] The analysis on the "old" firms in Layer III have to be treated carefully, as it only includes 7 firms for Europe, 7 firms for the US and 4 firms for Asia.

innovation based growth?   This section looks at one possible avenue for explaining, namely a failure in the European ICT innovation system to generate a symbiosis between young and established firms. Baumol (2004) noted how fortunate the US has been to have such a symbiosis of young firms introducing breakthrough innovations, while the established large firms, in a mix of cooperation and competition with these young firms, make the follow-up innovations and further improve the breakthrough innovations of the former. It happens more smoothly in the US that larger more established firms in the ICT eco-system, often themselves being still relatively “young”, acquire the technology of the young start-ups through licensing or take-overs. Europe might be missing a similar symbiosis between young and old incumbent firms interacting with a mix of competition and cooperation, thus failing to provide a more accommodating environment for new young ideas to scale up into global game changers.

Innovation ecosystems very often entail strong geographical dimensions, which are crucial in shaping the system dynamics (Dosso et al (2015)). Geographic proximity may provide a considerable advantage when it comes to finding clients, suppliers, funders and partners for cooperation. Clusters bring together different firms, both start-ups and incumbents, horizontally and vertically related firms from all layers (I, II and III) but also firms providing supporting business services and risk capital and research institutes, bringing together infrastructure, skills, finance and professional support. When actors are based close together they intensify their interactions, both cooperatively and competitively.

Various local clusters are observed in digital markets, the most notable example being US Silicon Valley. But also in Europe digital clusters prevail, recent examples being Berlin and London’s Silicon Roundabout, where a mix of private incubators, external investment from large ICT companies (often non-European, like Cisco, Intel, Google, Microsoft), academic institutions, and albeit with less importance, government policy support, created a bustling digital start-up scene. And many more regions aspire to be the next Silicon Valley in Europe. Nevertheless, it is unclear whether these digital clusters are sufficient in numbers, scale and ecology to sufficiently nurture dynamic young world leading innovators.

This section takes a glimpse at the clustering of ICT firms in EU regions and their composition of young and old ICT firms. To this end we use data from the Amadeus database on number of firms in all sectors and ICT sectors in particular[4] from 122 NUTS2 regions in the large EU countries (Germany, France, UK, Italy and the Netherlands) for the year=2009[5]. **Young** firms are those enterprises up to 5 years old. Within the group of young firms, we look at **Gazelles**, defined, using the OECD definition as those young firms with

[4] We use the OECD classification to identify **ICT sectors** (both manufacturing and services)The ISIC Rev. 3 classes included in the definition are: **Manufacturing**: 3000 – Office, accounting and computing machinery; 3130 – Insulated wire and cable; 3210 –Electronic valves and tubes and other electronic components; 3220 – Television and radio transmitters and apparatus for line telephony and line telegraphy; 3230 – Television and radio receivers, sound or video recording or reproducing apparatus and associated goods; 3312 – Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process equipment; 3313 – Industrial process equipment. **Services**: 5150 – Wholesaling of machinery, equipment and supplies (if possible only the wholesaling of ICT goods should be included); 7123 – Renting of office machinery and equipment (including computers); 6420 –Telecommunications; 72 – Computer and related activities.

[5] The year 2009 allows for enough time to assess growth performance.

average annualised growth greater than 20% per annum, over a three year period. [6] **Large** firms are those firms with more than 250 employees. The 122 European regions represent 704 young ICT firms, 129 ICT gazelles and 947 large ICT firms.

A first observation from the data is that compared to other sectors, ICT sectors are more intensive in young firms and especially in gazelles: 3.7% of all large firms are found in ICT sectors, 3.9% of all young firms, 6.2% of all gazelle firms. These numbers confirm that ICT sectors are an important source of opportunity for entry and fast growth of new firms, even in Europe.

We next look at the phenomenon of regional clustering of ICT firms. To this end we calculate Herfindahl concentration ratios (H). The higher is H, the more concentrated the distribution of firms in few regions. If firms would be distributed equally across all regions, the H-index would be 1/N with N the number of regions (in casu: 0.0008 would be the minimal value). The Number Equivalent (NE) indicates the number of equally sized regions it would require to generate the same H value. The higher the NE, the more even spread the number of firms is across regions.

Table 6: Regional concentration of ICT firms in Europe

	ICT sectors		All Sectors	
	H	**NE**	**H**	**NE**
All firms	0.019	51	0.013	75
Young firms	0.033	30	0.020	51
Gazelles	0.044	23	0.022	46
Large firms	0.028	36	0.016	63

Note: $H_c = \sum_r s_r^c . s_r^c$ with ^{c} class of companies (All, ICT, Young, Gazelles, Large); s_r^c= share of region r in total number of companies of class c; $NE_c = 1/H_c$;

Source: Calculations on the basis of Amadeus, 2009.

Table 6 shows how concentrated ICT firms are in EU regions. The higher H-index and lower NE shows that young ICT firms are more regionally concentrated than large ICT firms. ICT gazelles are even more regionally concentrated than young ICT firms. This also holds for all sectors, but the difference is more pronounced in ICT sectors. Young ICT firms, and especially gazelles, are therefore a phenomenon, highly regionally concentrated.

We next look at the composition of young and old ICT firms in these regional ICT clusters. In which regions do young ICT firms concentrate? Are they clustering in the same regions as large ICT firms? Are the regions

[6] Growth can be measured by the number of employees or by turnover. Enterprises should have at least 10 employees at the start of any observation period.

where the fast growing young ICT firms concentrate, the ones where young and large ICT firms co-cluster? The following tables examine this further.

Table 7: Co-Mapping the regional concentration of ICT firms by type

	Large ICT	Large All	Young All	Gazelle All
Young ICT	0.03	0.17	0.89	0.92
Gazelle ICT	0.08	0.27	0.76	0.84

Note: Table reports the correlation coefficients between the share of the regions in the total number of firms by type.

Source: Calculations on the basis of Amadeus (2009)

The low correlation coefficient between the number of large ICT and Young/Gazelle ICT in EU regions indicate that the regional concentration mapping of large ICT firms only weakly coincides with the regional concentration mapping of young/gazelle ICT firms. Actually, the young/gazelle ICT regions co-map better with large firms from other sectors than from ICT sectors. The high correlation between the regional mapping of young and gazelle firms indicate that young ICT firms are more likely to become gazelles in regions with a vibrant start-up scene.

Table 8 further investigates this divergent regional mapping of young and large ICT firms. It shows that the regions which have an above average share of young ICT firms (regions with a comparative advantage in young ICT firms) are typically not the regions which at the same time have a comparative advantage in large ICT firms. Regions with a specialization in young ICT firms, while hosting 82% of all young ICT firms in the sample, only host 17% of large ICT firms. Only 5% of these regions also hold a share of large ICT firms above average, with their average specialization rate in large ICT firms being only 0.38. And vice versa, the regions which a specialization in large ICT firms, while hosting 76% of all large ICT firms, only host 13% of all young ICT firms. Only 7% of these regions also hold a comparative advantage in young ICT firms.

Table 8: Regional mapping of young and large ICT firm

Regions with a comparative advantage in Young ICT firms (38 out of 122)	
Share of all young ICT firms	82%
Share of all large ICT firms	17%
Share of regions with a comparative advantage in Large ICT firms	5%
Average specialization ratio in Large ICT firms	0.38

Regions with a comparative advantage in Large ICT firms (41 out of 122)	
Share of all young ICT firms	13%
Share all all large ICT firms	76%
Share of regions with a comparative advantage in Young ICT firms:	7%
Average specialization ratio in Young ICT firms	0.34

Note: The specialization ratio of the region for a particular type of company is calculated as follows: $NrFirms^{c}_{r}/NrFirms^{c}_{all}$ / $NrFirms^{all}_{r}/NrFirms^{all}_{all}$ with superscript c denoting the type of firm (young ICT, large ICT, large All) and subscript r denoting the region. If this ratio is above 1 for a type c firm, the region specializes in type c firms. It holds a comparative advantage in type c firms.

Source: Calculations using Amadeus (2009)

Table 9 takes a closer look at those young ICT firms which manage to grow fast, turning into gazelles. We look at the regions which succeed the best in having their young ICT firms turn into gazelles. We are particularly interested in seeing whether these are the regions where young and large ICT firms co-map.

Table 9: Regional mapping of ICT gazelle regions

	Regions with an above average gazelle rate among young ICT firms		Regions with a below average gazelle rate among young ICT firms	
Average specialization rate/ Number of regions with specialization				
Large ICT firms	0.68	9	0.92	21
Young ICT firms	1.26	19	0.92	19
Young firms (all sectors)	1.09	17	1.07	25
Large firms (all sectors)	0.93	20	0.95	30

Note: Excluded are regions (N=30) which have no young ICT firms; The regions are split according to whether $NrICTgazelles_r/NrICTyoung_r$ >< $NrICTgazelles_{all}/NrICTyoung_{all}$: 37 regions have an above average gazelle rate, while 55 regions a below average.

Source: Bruegel Calculations

The regions with an above average rate of gazelles among its young ICT firms, tend to have an above average share of young ICT firms and young firms in general. This illustrates again that in order for a region to have fast moving ICT gazelles, it is important to have a big pool of young start-ups, among which gazelles will emerge, reflecting that it is a process of experimentation rather than an ex ante selected few which generates gazelles.

The regions which succeed in having an above average gazelle rate among their young ICT firms are not characterized by above average rates of large ICT firms. Indeed, the regions with below average gazelle rates among young ICT firms tend to have higher specialization rates in large ICT firms. Again this illustrates the divergent geographic mapping between young and large ICT firms and the potential problem of missing symbiosis between large and young ICT firms. The mapping with large companies from all sectors is better than with large ICT firms.

6. Eco-systems impediments in Europe: implications for policy design

With the post-internet ICT eco-system shifting power inside the system to platform, content and application providers (Layer III), the analysis clearly show how poorly positioned Europe is in the post-Internet ICT innovation ecosystem, holding less world leading innovators in Layer III, which are typically young, highly R&D intensive world leading innovators with expanding R&D budgets and sales. Europe's struggling R&D position in the ICT eco-system is therefore clearly related to its age and layer composition and its failure to sufficiently redirect with young innovators towards Layer III.

A further look at the regional clustering of ICT firms in Europe, reveals that the regional concentration mapping of large ICT firms only weakly coincides with the regional concentration mapping of young ICT firms and that the regions which succeed in having an above average gazelle rate among their young ICT firms are not characterized by above average rates of large ICT firms. These observations point in the direction of the potential problem of missing symbiosis between large and young ICT firms to explain Europe's failing ICT innovation potential.

At this stage, the evidence provided in this contribution is still too sketchy and needs further and deeper analysis, before it can feed into evidence based policy making. Nevertheless, it shows the importance of a good understanding the characteristics of the post-Internet ICT eco-system, particularly the shifts towards the upper layer of network providers, software and applications and the implications this has on the age structure of leading innovators and the interactions between young and more established innovators between and within platforms, crossing different layers in the eco-system. At the same time, policymakers should also appreciate the dynamics of the ICT eco-system with high velocity, systemic interdependencies, path dependencies and fluid boundaries.

Nevertheless, some tentative policy directions can be highlighted. To address **digital eco-system failures**, policy could support the initial phases of interface building between new digital innovators and potential cooperation partners. **Innovation partnerships** in the form of large R&D consortia, such as the Framework Programme projects funded by the European Commission, may have helped to create momentum for technology and industry enabling. Nevertheless, the process of public funding allocation is often seen as too slow when compared to the speed of evolution in digital markets, missing out on new, disruptive opportunities. Furthermore, innovation partnerships in the form of large R&D consortia are not found to be particularly supportive for small and young innovators in new emerging markets (Veugelers (2012)).

Also the deployment of **competition policy** for supporting the interface building between entrants and incumbents in digital markets is challenging, both for its mergers as well as its anti-trust component What is clear is that a standard static equilibrium approach will not do. A more dynamic approach requires taking into account incentives for investing in new technologies, not only by the parties currently on the market, be they incumbents or entrants, but also on future potential entrants with new disruptive solutions. Dynamic competition effects shaping the future working of ICT innovative markets should be much higher on the radar of competition policy authorities.

With a highly complex area to address and limited evidence about how to best implement policy instruments, designing an appropriate EU policy for new ICT markets is bound to be a challenging endeavour. There are still too many unknowns about whether and which government interventions are effective for supporting the development of new ICT markets. Any policy intervention and policy advice should therefore be handled with great care. With too many unknowns about whether and which policy interventions are effective, policymakers should engage in **close monitoring of emerging technologies and markets.** **An ICT market monitoring unit** could be set up at central EC level which would advise the various Directorates involved on emerging trends in the ICT eco-system. It should evaluate whether the right mix of general and specific policy instruments is present to allow the development of new ICT market opportunities for Europe and which interventions should be adapted or dropped when they are impeding.

This monitoring capacity should include a strong prospective angle which is able to identify new emerging markets well in advance and to have a pro-active policy mix already prepared for the pre-natal phases of development.

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